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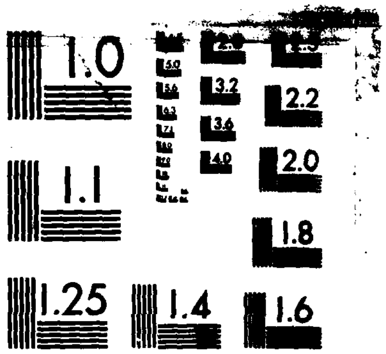

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TEST EQUIPMENT MANAGEMENT

January 1985

Frans Nauta
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The Department of Defense's investment in fielded test equipment (manual and automatic test equipment and test program sets) exceeds $30 billion and is increasing rapidly. The problems associated with acquiring and supporting test equipment are varied and significant. Much of it does not work as well as expected, is both difficult and costly to support, and is not suitable for its planned operational environment. For some test equipment, the Military Departments lack the assets necessary to support peacetime operating tempos, let alone those expected during wartime.

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Since the early 1970's, the Office of the Secretary of Defense and the Military Departments have sponsored numerous studies of test equipment. Those studies have repeatedly documented the problems and identified the solutions. Some solutions implementable through the acquisition process are being pursued; however, those that require changes in the management and support of test equipment after it enters the inventory are not receiving similar attention. The authors suggest some changes.

We believe that the Assistant Secretary of Defense (Manpower, Installations and Logistics) must be the catalyst to effect those changes within the Department of Defense. We recommend he charge the Director, Maintenance Policy, to take the following actions to correct long-standing problems in test equipment management: develop a Department of Defense-wide preferred item list for manual test equipment, institute reporting of automatic test equipment performance and availability, establish procedures for collecting test program set run times and performance data, and draft a Department of Defense instruction that prescribes policy and procedures for managing and supporting test equipment.

A-1

Executive Summary

TEST EQUIPMENT MANAGEMENT

The Department of Defense's (DoD's) investment in fielded test equipment (manual and automatic test equipment and test program sets) exceeds $30 billion and is increasing rapidly.

The problems associated with acquiring and supporting test equipment are varied and significant. Much of it does not work as well as expected, is both difficult and costly to support, and is not suitable for its planned operational environment. For some test equipment, the Military Departments lack the assets necessary to support peacetime operating tempos, let alone those expected during wartime. The consequences go beyond the dollars already invested in test equipment and the annual cost of its support: weapon system readiness suffers from inaccurate, delayed, or prolonged testing; and depot maintenance workloads are increased unnecessarily with field-reparable modules and components because test equipment in the field is neither available nor operational.

Since the early 1970's, the Office of the Secretary of Defense (OSD) and the Military Departments have sponsored numerous studies of test equipment. Those studies have repeatedly documented the problems and identified the solutions. Some solutions implementable through the acquisition process are being pursued: greater emphasis is being placed on support during development; procurement of test equipment is being delayed until weapon system designs stabilize; and standardized automatic test equipment is being developed. However, those solutions that require changes in the management and support of test equipment after it enters the inventory are not receiving similar attention.

It is time for the DoD to take the actions that are fundamental to an effective test equipment management program. OSD must curb the proliferation of many different types of manual test equipment; improve the reliability and maintenance support of automatic test equipment; and shorten run times and improve the diagnostic performance of test program sets.

We believe that the Assistant Secretary of Defense (Manpower, Installations, and Logistics) must be the catalyst to effect these and other actions within the DoD. We recommend he charge the Director, Maintenance Policy, to take the following actions to correct longstanding problems in test equipment management:

- Develop a DoD-wide preferred items list for manual test equipment;
- Institute reporting of automatic test equipment performance and availability;
- Establish procedures for collecting test program set run times and performance data;
- Draft a DoD instruction that prescribes policy and procedures for managing and supporting test equipment.

These actions constitute a small, first step toward improving management and support of test equipment within the DoD. However, they will signal the Military Departments that the problems with fielded test equipment must be corrected and that OSD intends to lead the way.

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1. BACKGROUND

Since the early 1970's, the Office of the Secretary of Defense (OSD), the Military Departments, and industry have sponsored numerous studies of test equipment, formed several joint panels to investigate selected technical issues in more detail, and initiated a variety of programs to correct identified problems. Despite such attention over many years, the Department of Defense (DoD) still faces many significant problems with its test equipment. Most of the problems are technical in nature; several, however, can be traced directly to shortfalls in management. Throughout this report, we make extensive use of previous studies of test equipment to draw conclusions about those problems and shortfalls and to identify areas in which increased OSD participation would enhance the development of permanent solutions.

This chapter defines the terminology used throughout the report, provides an estimate of the value of DoD's inventory of test equipment, and describes the organization of the balance of the report.

TERMINOLOGY

Each of the Military Departments, as well as OSD, has adopted its own nomenclature for test equipment. Even though the Army has an official definition for "test equipment," it seldom uses that term. The term most frequently used by the Army is "test, measurement and diagnostic equipment (TMDE)," and it is defined below.

> Any system or device used to evaluate the operational condition of an end item or subsystem thereof, or to identify and/or isolate any actual or potential malfunction. TMDE includes diagnostic and prognostic equipment,

> semiautomatic and automatic test equipment (with issued software), and calibration test or measurement equipment.[1]

The Navy considers "electronic test equipment (ETE)" to include both manual and automatic test equipment (ATE). It further categorizes manual ETE either as general or special (i.e., designed to support a particular weapon system) purpose.

The Air Force treats test equipment as just one category of support equipment, as illustrated by the following definition.

> Support equipment includes all supporting equipment except equipment that is an integral part of the mission equipment. It includes: tools; test equipment; ATE; organizational, field, and depot support equipment; related computer programs and software.[2]

For the most part, however, the Air Force refers to manual test equipment, ATE, and associated software jointly as precision measurement equipment, a term unique to the Air Force.

The DoD does not define either test equipment or TMDE, but does use the term "support and test equipment," as defined below, in the budget process.

> . . . development and procurement of peculiar support and test equipment (e.g., test program sets) and major items of common ST&E [support and test equipment] (automated test station, fuel storage, and handling equipment, etc.) required for the new system.[3]

Each of the Military Departments considers ATE to be essentially the same thing:

> Equipment that is designed to conduct analysis of functional or static parameters to evaluate the degree of

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[1]Department of the Army, "Test, Measurement and Diagnostic Equipment," Army Regulation 750-43, 1 April 1984.

[2]Department of the Air Force, "Acquisition of Support Equipment," Air Force Regulation 800-12, 20 May 1974.

[3]Office of the Secretary of Defense, Program Objectives Memorandum (POM) Preparation Instructions, Format V-E-1 Attachment, "Support Element Definitions," 1984.

performance degradation and may be designed to perform fault isolation of unit malfunctions. The decision making, control, or evaluative functions are conducted with minimum reliance on human intervention.[4]

An ATE station comprises numerous stimuli and measurement instruments interfaced with and under the control of a computer and supplemented with various input/output peripherals (e.g., display, printer, control station). Some of the instruments integral to the ATE may be identical to ETE used manually. The ATE examines a particular item (known as the "unit under test" or UUT) by executing a test program set (TPS) designed for that item.

Each Military Department uses the term TPS, but the terminology for the elements constituting a TPS differs. The term TPS does not appear in MIL-STD-1309B but is defined in a Navy Military Standard[5] as consisting of those items necessary to test a particular unit using ATE. Those items include the test program (a coded sequence for automatically determining the operational readiness condition of the UUT), interface device (the connector between the ATE and UUT), test program instruction (the additional operator instructions needed to carry out the test), and supplementary data (the additional technical data needed for the test).

With the above definitions as a background, the term "test equipment" throughout this report refers to the composite of ETE (limited to manual test equipment only, including both general and special purpose), ATE, and TPSs.

IMPORTANCE

The need for effective test equipment management within the DoD is best illustrated by the DoD's already substantial investment in test equipment.

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[4]"Definition of Terms for Test, Measurement and Diagnostic Equipment," Military Standard (MIL-STD) 1309B, 30 May 1975.

[5]"Test Program Sets; General Requirements for," MIL-STD-2077(AS), 9 March 1978.

able 1-1 shows that the DoD has invested approximately $30 billion in test quipment, including more than $14 billion in ATE alone. It has in excess of 0,000 different makes and models of ETE (mostly in the Air Force) and 4,000 different TPSs (again, mostly in the Air Force).

TABLE 1-1. DoD's INVENTORY AND INVESTMENT IN TEST EQUIPMENT

TEST EQUIPMENT	ARMY	NAVY	AIR FORCE	TOTAL
ETE				
Line Items[1]	18,000	29,000	54,000	80,000+
Density[2]	730,000	700,000	800,000	2.2M[4]
Cost[3]	$3B[4]	$2.8B	$3.7B	$9.5B
ATE				
Line Items	110	352	425	880+
Density	N/A[5]	N/A	3,400	3,400+
Cost	$1B	$3.5B	$10B	$14.5B
TPS				
Line Items	1,000	5,000	8,000	14,000+
Cost	0.5B	$2.5B	$4B	$7B
			Total Cost	$31B

[1]Number of unique items or test programs as identified by stock number or computer program index number.

[2]Total number of items in the inventory.

[3]Initial investment including development and/or acquisition.

[4]B = billion; M = million.

[5]Not available.

The ETE data shown in Table 1-1 include only general-purpose equipment (which is categorized in Federal Supply Class (FSC) 6625). The number of ETE line items was taken from a recent DoD-wide report on the status of standardization for all ETE in FSC 6625.[6] All of the ETE cost data are approximations because that information is not available.

[6]United States Army Communications-Electronics Command, "Standardization Program Analysis, FSC 6625," Department of the Army, 29 June 1984.

Each Military Department knows the number of different types of ATE in s inventory, but only the Air Force knows how many it has of each type. The my monitors closely its general-purpose ATE (such as the AN/ USM-410, Elec- onics Quality Assurance Test Equipment -- EQUATE), but has difficulty eping track of special-purpose ATE. The Navy's situation is similar to that the Army. Furthermore, the ATE cost data are rough estimates only, taken ırgely from the literature.

The number of different types of TPSs shown in Table 1-1 is the order of ıgnitude as of the end of Fiscal Year (FY) 1984. The TPS costs are estimates ecause the Military Departments do not keep track of that data. The esti- ates shown are based on a factor of $500,000 for each unique TPS. Actual osts of currently fielded TPSs, based on contract data, range from a low of 30,000 to a high of $2.5 million, depending on UUT size and complexity, and he compatibility of the UUT with the ATE. The contract costs, however, do ot include the cost of developing TPS requirements specifications, the cost f spare UUTs for TPS validation and verification, the cost of ATE time needed or TPS development and verification, the cost of engineering changes to ccommodate UUT or ATE changes or to improve TPS performance, or the cost of oftware maintenance and configuration management. Consequently, the TPS cost stimates are probably conservative. (TPS density is not shown in Table 1-1 ecause copies can be made of unique TPSs at relatively small cost.)

Not only does the DoD have a substantial investment in test equipment, ut that investment is estimated to be growing by several billion dollars nnually.

EPORT ORGANIZATION

Chapter 2 provides an overview of the problems with test equipment. A ynopsis of numerous initiatives to correct the problems with test equipment presented in Chapter 3. Chapter 4 identifies several areas requiring reased participation from OSD and recommends that OSD undertake several cific actions.

Vertical Testability. The term "vertical testability" refers to the ent to which tests and test results are consistent among the three levels maintenance: organizational level (system BIT), intermediate level imarily line-replaceable unit testing), and depot level (shop-replaceable t testing). The manifestations of testability problems, such as high innot duplicate" and "retest okay" (RTOK) rates, traditionally have been ributed to system BIT shortfalls. However, recent Air Force studies of 11 BIT indicate that about 50 percent of the line-replaceable units testing od" on ATE are actually faulty, confirming the accuracy of aircraft BIT lications.[4] The F-111's ATE evidently cannot simulate the full spectrum of UUT's operational environment. If the ATE is supplemented with "dynamic sters" (i.e., hot mockups), then most vertical testability problems dis- pear. This example of inadequate vertical testability applies to other apon systems as well and may explain many of the unsatisfactory experiences th ATE.

ST PROGRAM SETS

The problems with TPSs are straightforward: they seldom are developed by e time the weapon system is fielded and when they become available, they ther are not as effective as planned or require major improvements within e first 2 years. (The Air Force estimates that 40 percent of its TPSs have jor deficiencies when they are fielded and that 90 percent must be modified thin 2 years of fielding.)[5] Furthermore, the Military Departments fre- ently lack the technical data for supported systems to make needed TPS provements. As a result, excessive delays in updating and/or improving TPSs

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[4]"Enhancing the F-111 Avionics Intermediate Shop with Dynamic Test Sta- ons," presented by Alton E. Patterson, Anthony Carnciro, and Eugene M. Long AUTOTESTCON '83.

[5]Air Force Logistics Command, "A Study of Embedded Computer Support stems," September 1980.

ncept for most fielded ATE is based on BIT fault isolating to a tester-placeable unit, which is either repaired on-site or evacuated to a higher-vel maintenance facility. Because of the high parts count of large-scale TE, the random behavior of failures in electronics equipment, the high reli-bility of individual components, and the low density of identical ATE at any nit, the demands for ATE spares and repair parts seldom meet demand stockage riteria, so that supply support for ATE is frequently inadequate. The Army's olution is to authorize an essential repair parts stockage list for ATE, hile the Navy and Air Force always deploy their ATE in pairs (or more), ermitting the cannibalization of one ATE to keep the other(s) operational. he latter approach is acceptable in peacetime (cost studies have actually hown that a complete standby ATE is often cheaper than stocking all ATE arts), but it fails in wartime, particularly for the Air Force. In war, the ir Force plans to deploy a three-squadron tactical air wing with three sets f ATE to two locations, one of the locations would be assigned two squadrons and the associated ATE). The squadron assigned to the other location would hen be supported by just the one set of ATE.

Compatibility. To be effective, both the ATE and the items to be ested must be compatible. If prime equipment design proceeds without etailed specification of the ATE, the logical consequence is incompatibility. his incompatibility creates either a need for special-purpose ATE (contribut-ng to proliferation) or complex interface devices to use the standard ATE contributing to excessive TPS run times). The Navy's S-3A aircraft provides n example of the latter situation. To overcome the incompatibility between S-3A assemblies and VAST, the Navy had to develop a complex interface device o slow down the electronic clock speed of the assemblies to match that of VAST. The clock speeds were matched, but TPS run time, in turn, increased.

ime losses, with most line-replaceable units requiring a unique interface evice; low TPS quality as indicated by excessive run times and ambiguity of ault-isolation resolution; and a much higher workload (numbers of UUTs to be rocessed) than estimated on the basis of reliability parameters of the supported weapon systems. To compensate, the Military Departments either field dditional ATE or off-load work to other ATE.

Durability. ATE is extremely fragile equipment, sensitive to temperature, humidity, dust, shocks, and quality of electric power supply. Yet, understandably, the Military Departments continue to stress the use of that equipment in environments in which those factors are extremely difficult to control. To illustrate, field-level ATE in the Army may be deployed in truck-mounted vans or in trailer-mounted shelters. The operational environment for those vans and shelters is severe, characterized by movement over rough terrain, frequent relocation (at least in wartime), and inconsistent power supply and air conditioning. It is not surprising that the Army has had considerable difficulty developing ATE to be effective in the field.

Reliability, Maintainability, and Availability. The reliability of currently fielded ATE, as measured by mean time between failures (MTBF), is relatively low compared to their workloads and to the typical run times for TPSs. For example, the ATE stations of the F-15 AIS each have an MTBF of 35 to 40 hours; the reliability of the MSM-105s is in the same range; and the VAST, at least for aircraft carrier installations, has an MTBF of 40 to 50 hours. Low reliability, however, does not necessarily translate directly into low operational availability since no single TPS requires all of the stimulus and measurement capabilities of the ATE. Thus, even with one or more failures in test instruments, the ATE is still capable of executing many TPSs as long as the computer and core modules are operational. The maintenance (the length of time varies by manufacturer). Even though work-around procedures are developed, the ATE itself then becomes very difficult to support.

The combined effect of these three obsolescence factors -- engineering changes, equipment wearout, and discontinued commercial equipment -- is a relatively short economic life for ATE. The Air Force's on-going replacement of the AISs for its F-15 and F-16 aircraft illustrates this situation clearly. Those AISs were originally fielded in the mid- to late-1970's.

Operational Suitability

The requirements or specifications for ATE normally are stated in terms of performance or capability characteristics, such as number of input/output pins, vector pattern depth, clock rate, source/sink current, and program logic level resolution. Occasionally, the Military Departments acquire ATE that satisfies those technical characteristics, yet fails to provide the required support. Some of the contributing factors are discussed below.

Complexity. Much of the DoD's inventory of ATE consists of second-generation ATE, with a "rack and stack" architecture comprising many bays of test instruments and designed to be capable of testing a wide variety of equipment. The result is extremely complex ATE. Typical examples include the Air Force's F-15 AIS, which is more complex than the weapon system itself, and the Navy's VAST. The implications of the high, inherent complexity of ATE are low reliability and poor maintainability.

Throughput Capacity. The productive throughput of ATE stations at the intermediate level is often less than originally anticipated or planned. Factors contributing to this situation include: low reliability and inadequate maintainability of the ATE; queuing problems (e.g., both VAST and EQUATE are single-port systems, capable of serving only one UUT at a time); hook-up but a number of other factors have contributed. Three are briefly discussed below.

Prime Equipment Engineering Changes. Engineering changes or equipment upgrades are frequent in the electronics subsystems of prime weapon systems. Even though the weapon system itself may have a lifetime of 30 years, its electronics are probably updated every 4 to 7 years. Whenever that updating occurs, the original ATE invariably needs to be redesigned or replaced. In the past, redesign of ATE was complicated by a lack of standardization in test software languages, ATE operating software, and ATE design architecture. With the introduction of fourth-generation ATE, ATE redesign will become an easier task because prime equipment upgrades will be supported without replacing the entire ATE.

Hardware Wearout. Even if prime equipment engineering changes can be accommodated without major ATE design changes, that option is often impractical because the ATE already has exceeded its design life. It is common for the Military Departments to use ATE to such an extent that its design life (typically, 20,000 operating hours) is reached in 5, rather than 20, years. This need to operate available ATE so intensely occurs because (1) the ATE cannot provide the required throughput capacity or (2) the required number of ATE units to support peacetime operations are never procured.

Discontinued Commercial Equipment. ATE normally is composed of a mixture of commercial test instruments and instruments designed to military specifications, with the former being increasingly used because of their cost and schedule advantages over the latter. Commercial test instruments, however, are typically in production only a short time before being dropped from the manufacturer's catalog. Within a few years, the spares and repair parts for those out-of-production test instruments are frequently unavailable have tended to select specially designed test equipment. The result has been a proliferation of ATE, with little compatibility.

Attempts to control the proliferation of ATE often have created more problems than they have cured. In the early 1970's, the Air Force developed the General Purpose Automatic Test System as its standard depot-level ATE for testing shop-replaceable units. For a variety of reasons (technical as well as resistance by program managers), this program did not succeed. In 1972, the Naval Air Systems Command (NAVAIR) adopted the AN/USM-247 Versatile Avionics Shop Tester (VAST) as its standard for both intermediate and depot level. That decision, however, soon resulted in many unforeseen problems, including the limited productive throughput of VAST, the incompatibility of VAST with many of the units that it was to support, and the fact that the size and complexity of VAST made it too difficult to support. As a result of those problems, the Navy was forced to develop additional ATE to augment VAST.

The Army's first major attempt at standardizing its ATE occurred several years after those of the Air Force and Navy, but with similar results. In 1979, the Army adopted the AN/USM-410 EQUATE as the standard ATE for both general support and depot maintenance. At the general-support level, the Army plans called for development of two mobile, van-mounted versions of EQUATE: the MSM-105(V)1 for communications-electronics equipment and the MSM-105(V)2 for avionics (such as that aboard the AH-64 helicopter). When the first MSM-105(V)1 vans were fielded in the fall of 1983, representing early 1970's technology, the Army began to experience many of the same problems that the Air Force and Navy faced several years earlier.

Obsolescence

Rapid obsolescence is a serious problem with ATE, even more so than with ETE. One factor, the rapid evolution in ATE technology, has dominated, consists of portable testers that differ from each other primarily in the degree of automation and the extent of manual intervention required. Many of the testers currently in use require extensive operator interaction and, therefore, probably should be considered special-purpose ETE, not ATE. However, when the checkout functions are fully automated, such as in the Army's family of Simplified Test Equipment for internal combustion engines and combat vehicles, then the equipment clearly qualifies as ATE.

Off-line ATE is used principally at intermediate-level activities and depots. Typically, it is used to test and fault-isolate modules, assemblies, and components that have been removed from the prime equipment.

A third way of categorizing ATE, particularly off-line, is by interface technology. Currently, the UUT is stimulated and the response to that stimulation is measured through edge connectors, or input/output pins. With earlier ATE, however, a different technique, known as "bed of nails," was popular. (It is still used extensively in plant checkout equipment.) This technique probes the circuitry within the UUT directly, rather than indirectly via the input/output pins.

Most of the problems associated with ATE are tied directly to the rapid advancement in technology that has taken place in the past 25 years. This advancement has resulted in many different types of ATE in Military Department inventories (although all three have initiated major standardization programs); much of the ATE is obsolete; and much of it is not suitable for its planned operational environment.

Proliferation of ATE

Most of the ATE in the DoD's inventory has been acquired as support equipment for major weapon systems, with the program manager of the prime equipment responsible for developing ATE requirements. The program managers

TABLE 2-1. CHARACTERISTICS OF SUCCESSIVE GENERATIONS OF ATE

CHARACTERISTICS	FIRST GENERATION (1955 - 1965)	SECOND GENERATION (1962 - 1975)	THIRD GENERATION (1974 - 1980)	FOURTH GENERATION (1979 - PRESENT)
Instrument Design	Single-function manual instruments adapted to be programmable by ATE manufacturer.	Single-function manual instruments adapted to be programmable by instrument manufacturer.	Multiple-function waveform analyzers and synthesizers form core of system, with discrete instruments added.	Smart instruments, with microprocessors, standard bus compatible. Higher frequency waveform analyzers and synthesizers.
Control Method	Specially designed digital logic, read only memory, perforated tape bulk memory.	General-purpose computer, read/write memory, magnetic tape bulk memory. Control panel interface.	Commercial minicomputer, read/write memory, multiple bulk memories including disc.	Minicomputer and microcomputers, larger core memories, extensive
System Architecture	Custom design, parallel control, serial data flow, random organization. Add-on software. Multiple connector interface.	Custom arrangement of standard building blocks, parallel control, serial and parallel data flow. Add-on software. Patchboard interface.	Expandable "core" designs form families of testers with signal and control bases, integrated hardware/software design. More sophisticated interfaces, including pin electronics.	Standard multiplex data bus (IEEE 488), high-speed digital interface, integrated hardware/software, pin electronic interfaces.
System Software	Rudimentary executive programs, supported entirely by off-line assembler-peculiar test language.	More sophisticated executive program, supported by off-line compiler with "company standard" test language.	Multitask operating systems supported by on-line interpreters and off-line programming aids. Adapted ATLAS test language.	Multitask operating system, on-line interpreters and test pattern operators using guided probe. ATLAS subset.
Component Technology	Discrete components and vacuum tubes.	Discrete components and semiconductor active elements.	Discrete semiconductors and medium-scale integration integrated circuits.	Mix of discrete analog, analog IC, MSI, and large-scale integration integrated circuits.
Man-Machine Interface	Station controlled by complex operator/maintenance panel. Test results displayed on "nixie" tubes or printed on rolled paper.	Station controlled by simplified operator/maintenance panel and typewriter keyboard. Test results displayed using alphanumeric lights or printed paper.	Principal control through keyboard with black/white alphanumeric CRT display. Test results displayed on CRT and/or printed on wide paper.	Principal control through solid-state keyboard and color CRT display with alphanumeric and graphic capabilities. Test results displayed, printed, and recorded.

SOURCE: F. Liquori, Automatic Test Equipment Seminar Notes, Naval Air Engineering Center, Support Engineering, ATE Branch, Lakehurst, New Jersey, 1983.

The main reason, today, why the Military Departments continue using military specifications for general-purpose ETE is their desire to exercise complete configuration control. This makes the job of managing the test equipment and its life-cycle support easier but invariably results in higher costs in the short-run and greater technical obsolescence in the long-run.

AUTOMATIC TEST EQUIPMENT

The use of ATE by the Military Departments has been the focus of numerous studies, dating from the early 1970's. Many of those studies were initiated because of the effect that ATE has on weapon system readiness and because of its high cost.

Within the past 25 years, four different generations of ATE have been developed, with each succeeding generation being more capable, more effective, more efficient, and more supportable than its predecessor. (Table 2-1 describes the characteristics of each of the four generations.) Most of the ATE in the DoD's inventory is primarily second generation, with some third generation equipment such as the Air Force's avionics intermediate shop (AIS) for the F-16, some members of the Navy's "standard ATE family," and the Army's AN/USM-410 EQUATE, which is early third generation. Fourth-generation ATE will be introduced shortly by the Air Force, under its Modular Automatic Test Equipment (MATE) Program, but it will be several years before the Army and Navy are in a similar position.

Another way of categorizing ATE is whether it is used on-line or off-line. On-line ATE is primarily used by organizational-level mechanics. It is connected directly to the prime equipment, essentially to supplement the built-in-test (BIT) and/or in lieu of manual ETE.[3] On-line ATE usually

[3]This terminology differs from that used by many people where on-line ATE is considered to be BIT hardware/software embedded in the prime equipment.

commercial ETE may become obsolete from a support perspective soon after the manufacturer stops producing it, primarily because spare parts are no longer readily available. For out-of-production ETE built to military specifications, it may be relatively easy for a Military Department to find a source for spare parts and repair because it has all the needed specifications. Eventually, however, even that equipment cannot be supported economically. Both types of support obsolescence are common within the DoD.

Unnecessary Requirements

The Military Departments routinely specify ETE performance and support requirements that are not necessary and inflate the cost of acquiring and supporting that equipment.

Much of DoD's ETE continues to be built to military specifications, which stress high reliability and performance in a hostile environment. This practice, however, assumes that military-designed equipment is inherently more reliable than commercial ETE. This assumption may have been well founded several years ago, but it is no longer valid. Furthermore, the requirement for operating the ETE in a hostile environment appears sometimes to be more of desire than of need.

In addition to building much of its ETE to military specifications, the DoD also stresses that it be maintainable by military personnel. This requirement is in marked contrast to that of the commercial sector, for which many ETE manufacturers design their equipment to be repaired in factories or specially equipped repair centers. As a result, commercial ETE is much less likely than military ETE to embody functional partitioning of components, accessibility, and other design-for-maintenance features. Commercial ETE is, however, less costly because those features add substantially to both ETE design and production costs.

calibration requirements have not changed. The Air Force believes that this new equipment will perform the calibration faster and, over the long-term, will be more economical than existing equipment. The manual calibration equipment becomes technically obsolete with the first delivery of the newer equipment.

Special-purpose ETE is frequently rendered technically obsolete when weapon systems are modified to increase performance or to expand capabilities. If those modifications introduce new requirements for special-purpose ETE, the old test equipment no longer can be used.

One of the primary reasons that general-purpose ETE becomes technically obsolete is that budget requests for replacement equipment are not adequately supported. Since this equipment does not have a strong constituency with the DoD, it is not uncommon for those requests to be routinely reduced or even eliminated. Eventually, however, replacement equipment must be procured. The Air Force recently faced such a situation with its precision measurement equipment laboratories. The Air Force had not updated the equipment in those laboratories for many years, so much of it was obsolete. As a consequence, the Air Force was forced to quickly establish a substantial equipment upgrade program for its laboratories.

General-purpose ETE actually becomes obsolete very quickly. The average production life of this type of equipment in commercial markets is 5 to 7 years, and when a new model is developed, the production of the old model is often terminated immediately. If that equipment is in the DoD's inventory, then problems in supporting it surface quickly.

Support Obsolescence. An item of ETE is obsolete from a support point of view when spare parts, technical manuals, training, depot repair, or other support no longer can be economically obtained. As noted above, overall effect of these failures is a steady stream of new and unique ETE being procured by the Military Departments.

Acquisition Practices. The second major contributor to the proliferation of ETE within the DoD is the frequency with which the Military Departments give a prime contractor extensive latitude in selecting and developing the ETE to support a major weapon system. It is common for a Military Department to establish a line for ETE in the basic contract without specifying the types of ETE that will be provided, the quantity of each type required, and when the ETE will be delivered. Those specifics are then negotiated after development of the weapon system has begun, at great disadvantage to the Government both in terms of managing costs and controlling the proliferation of ETE. Similarly, reprocurement of a specific type of test equipment is often opened to competition, resulting in a growing mix of different makes and models of the same type of test equipment.

Obsolescence

Within the DoD, ETE becomes obsolete when it is technically outdated or when it no longer can be supported. Both forms of obsolescence are more common with general-purpose ETE than with special-purpose ETE.

Technical Obsolescence. Technical obsolescence occurs when new requirements for test equipment cannot be met by ETE already in the inventory. An example would be a military mechanic attempting to troubleshoot a digital computer system with test equipment incapable of measuring the time intervals needed. Although this example of technology transcending available ETE is common (as well as expected) within the DoD, technical obsolescence of ETE is also driven by changes in requirements and operating environments. As an example, the Air Force recently initiated a program to replace much of its manual calibration equipment with automated equipment, even though the

To place the proliferation in even more concrete terms, the Army, as part of its TMDE Modernization Program, bought 10 new types of general-purpose ETE in FY82. Those 10 replaced 650 different makes and models in the Army's inventory. Additional purchases of other types of general-purpose ETE are planned over a 10-year time frame.

The causes of ETE proliferation are numerous, but many can be traced to shortcomings in the validation of technical requirements and in the practices followed in acquiring new ETE.

Technical Requirements. A common form for specifying ETE requirements, particularly for aviation weapon systems, is the Support Equipment Recommendation Data (SERD). The prime contractor for the weapon system usually prepares the SERD and then forwards it to a military activity that specializes in reviewing requirements for support equipment. That activity ascertains that the requirements for new general-purpose ETE cannot be satisfied by items already in the inventory and that the requirements for special-purpose ETE are valid.

In practice, this process fails to control the proliferation of ETE because (1) the support equipment activities are given only 60 days to review each SERD, a period that in many cases is inadequate (the B-1 aircraft alone generated 9,000 SERDs; annually, the Air Force processes more than 30,000 SERDs); (2) many SERDs are incomplete and thus require additional attention from activity personnel (the Air Force estimates that 35 percent of its SERDs are not properly completed); (3) the reviewing activities have neither an up-to-date listing of preferred ETE nor the authority to require that already available ETE be used; and (4) prime contractors (and the program managers) routinely submit SERDs for special-purpose ETE or new general-purpose ETE irrespective of the ETE already in the DoD's inventory. The

2. OVERVIEW OF TEST EQUIPMENT PROBLEMS

This chapter summarizes DoD's problems with test equipment, with separate treatment for ETE, ATE, and TPSs.

ELECTRONIC TEST EQUIPMENT

Many of the DoD's problems with ETE were first given extensive visibility by a Defense Science Board Task Force in 1976. During a 2-year period, the task force reviewed the DoD's acquisition and management of ETE and, based on the results of that review, developed 28 recommendations to correct observed problems. Even though several of the recommendations were fully implemented, many of the important problems identified by the task force still remain: the DoD's inventory of ETE consists of too many different line items (i.e., makes and models of ETE), with much of it obsolete and/or designed to satisfy unnecessary requirements.

Proliferation

The proliferation of ETE within the DoD can be best illustrated by comparing the number of different makes and models of ETE with the minimum number of different types required. Table 1-1 shows that the Army has more than 18,000 different makes and models of general-purpose ETE. Yet, one source concluded that the Army has a requirement for only 600 types of general-purpose ETE.[1] Similarly, in 1982 the Navy concluded that its total requirement for general-purpose ETE was fewer than 200 types,[2] not the 29,000 different makes and models shown in Table 1-1.

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[1]LTG J. M. Heiser, Jr., USA (Ret.), "Assessment of DA/DARCOM TMDE Program," September 1979.

[2]Department of the Navy, "Standard General Purpose Electronic Test Equipment," MIL-STD-1364F, 1 March 1982.

by contractors are typical, especially for TPSs used at the intermediate-maintenance level. For some systems, the costs associated with updating TPSs are deemed excessive and the updates are not procured. As an example, the Air Force is not updating the TPSs for F-15 line-replaceable units, developed at a cost in excess of $500 million, because of the cost. (To reduce program acquisition costs, the Air Force did not procure the technical data for F-15 line-replaceable units. Without that data, it is impossible to identify why TPS diagnostic performance is not satisfactory and to make necessary improvements.) Another factor contributing to this decision may be that those units are inadequately designed for testability.[6]

The problems of late development and inadequate performance of TPSs are caused by many factors, but three appear to dominate: the complexity of developing TPSs, the inherent limitations of acceptance tests, and the absence of management tools to monitor TPS performance and cost.

Complexity of TPS Development

The development of a TPS is a complex process. To compensate for that complexity, the Military Departments frequently do not adhere to established TPS development practices and standards and permit simplifying assumptions that, on the surface, save both time and money. Over the long run, however, those short-term savings result in the fielding of TPSs that are not available in a timely manner, are not effective, and are excessively costly.

Development of a TPS begins with the UUT test specifications. Establishing those specifications is a laborious, long, costly, and labor-intensive task. It is not unusual for weapon system contracts to be modified

[6]Poor design for testability of the prime equipment is one of the root causes of high cost and poor performance of currently fielded TPSs. The F-15's problems with testability are documented in "Minutes of the F-15 RTOK Management Group Meeting," Warner Robins Air Logistics Center/ Support Systems Associates, Inc., November 1982.

to waive many of the provisions for UUT test specifications. While this practice reduces the cost of the basic contract, it increases the difficulty of using organic resources to maintain and/or improve the TPS once it is developed, because the required technical data are not available.

Not only are the UUT test specifications costly to develop, the DoD does not yet have the tools and methods to verify and validate them. As a result, the DoD must rely on the contractor's assertion that the specifications are accurate and complete.

Following development of UUT test specifications, the contractor then designs the test program, test program instructions, and interface devices necessary to satisfy the specifications. To compensate for some of the complexity of that design, the Military Departments frequently permit contractors to use several simplifying assumptions. Those assumptions often limit the fault detection capability of the TPS to single, "hard" failures that occur within electronic components. Furthermore, failures caused by poor workmanship, design deficiencies, incorrect assembly in the factory, accidental damage, and UUT cannibalization are normally excepted from the TPS design logic. Thus, many of the failures that would be encountered in an operational environment, such as wiring failures, multiple failures, intermittent failures in digital modules, or components damaged from improper handling, often cannot be fault-isolated by the TPS.

<u>Limitations of TPS Acceptance Tests</u>

Acceptance testing of TPSs, whether developed in-house or under contract, is considered, by the Military Departments, to be just another standard quality assurance responsibility. The test essentially consists of selecting a small sample of possible UUT failures, inserting them one-by-one into a UUT test article, executing the TPS on the ATE in accordance with test program instructions, and observing the TPS's performance in detecting and isolating each failure accurately within specified levels of ambiguity. If the TPS passes the test, it is formally accepted. Copies are then made for distribution to maintenance activities and the TPS/UUT data are entered into a data base for configuration management.

This type of TPS acceptance test is inadequate however. A UUT may possess tens of thousands of different failure modes, many of which are not associated with the 10 or 20 failures that are inserted for the purposes of the test. Furthermore, the sample failures are selected from a contractor-prepared fault list.

It is, of course, impractical to conduct a complete, physical test of a TPS for a complex UUT. The DoD does not yet have the tools or the methods to verify TPS performance through other means (simulation). Until such time, the Military Departments must recognize that TPS acceptance testing represents, at best, a necessary but not sufficient tool for verifying TPS performance; rather, monitoring the performance of fielded TPSs appears to be an essential requirement.

Absence of Management Tools

The Military Departments have not developed the management tools necessary to ensure that their large investments in TPS development and support result in the fielding of high-quality TPSs. The costs of developing and supporting TPSs typically are not available, while the management systems for monitoring TPS performance are inadequate. The common explanation for the former is that the cost data are not required, while for the latter, the current procedures for collecting and reporting TPS deficiencies do not work for test program software.

One of the shortcomings frequently attributed to the current procedures for reporting TPS deficiencies is that they cannot adequately isolate deficiencies attributable to operator inexperience, ATE, ATE control software, UUT, interface devices, and TPS. The consequence is that TPS problems are routinely submerged, denying TPS developers and supporters the information needed to identify deficiencies and correct them.

Other important indications of TPS performance that need to be made available routinely are run time and diagnostic performance (i.e., fault-isolation resolution). The goal for a TPS developer is to design a TPS that always fault-isolates the UUT's problems in the shortest possible time. Yet, unless the diagnostic performances of TPSs and their run times are routinely recorded, improvement in TPS quality will be slow.

In the following chapter, we describe the numerous initiatives that OSD and the Military Departments have taken, or are taking, to correct the problems with test equipment.

3. SYNOPSIS OF DoD INITIATIVES

This chapter summarizes many of the key initiatives taken by the DoD in recent years to improve test equipment management and support.

JOINT OR COORDINATED INITIATIVES

In the late 1970's, the Joint Logistics Commanders (JLC) established a Panel on Automatic Testing to develop and implement a long-range, definitive program on automatic testing. The program, which was approved in 1979, comprises nearly 100 tasks divided into 3 categories: (1) management, (2) acquisition support, and (3) testing technology.[1] The efforts of that panel have resulted in the publication of several Joint-Service Guides (e.g., "Automatic Testing Acquisition Planning Guide," a "Built-in-Test Design Guide," and a "Selection Guide for Digital Test Program Generation System") and the development of improved automatic testing policies and procedures. The panel's efforts have also resulted in the initiation of several tasks, most of which are still ongoing, in the management and acquisition support categories.

In response to the findings of the 1976 Defense Science Board Study of ETE, the Deputy Under Secretary of Defense (Acquisition Policy) tasked the Defense Materiel Specifications and Standards Office (DMSSO) in 1980 to develop plans and procedures for reducing the proliferation of general-purpose ETE.[2] To carry out that tasking, DMSSO established the Ad Hoc DoD TMDE Standardization Group, comprised of representatives of the Under Secretary of

[1]"Joint Agreement on Support of the Automatic Testing Program," signed by the DARCOM/NMC/AFLC/AFSC Commanders, 16 July 1979.

[2]Deputy Under Secretary of Defense (Acquisition Policy), Memorandum for the Director, DMSSO, Subject: "Test, Measurement, and Diagnostic Equipment (TMDE), FSC 6625," 13 May 1980.

Defense for Research and Engineering (USDR&E) and the Military Departments. The primary emphasis of that group has been on eliminating military specifications for obsolete test equipment. It recently issued a status report on its standardization efforts[3] and is scheduled to publish a standardization plan in 1985.

Also in 1980, the JLC established a panel to examine the impediments to increased standardization of aviation ground support equipment (AGSE). The final report of the panel, which was issued in 1983, called for specific improvements in the areas of policies and procedures, data storage and retrieval, and contract methods and specifications.[4] The panel's recommendations included:

- Establish AGSE interservice coordination positions in each Military Service;
- Revise procedures for contractor review of AGSE data bases;
- Encourage AGSE acquisition managers to make standardization a major technical factor in source selection;
- Use Military-Handbook-300 as the primary data storage and retrieval system for ground support equipment identification and selection.

Although specifically focused on AGSE, many of the panel's recommendations are also applicable to other areas of test equipment. In approving the panel's report, the JLC agreed to implement most of the recommendations "within each of our Commands to the maximum reasonable extent as resources permit."

In 1982, the National Security Industrial Association (NSIA) established an Automatic Testing Committee to support and supplement the JLC Panel on Automatic Testing. Many of the tasks undertaken by the committee were in

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[3]Department of the Army, United States Army Communications Electronics Command, Standardization Program Analysis, 29 June 1984.

[4]Joint DARCOM/NMC/AFLC/AFSC Commanders Panel on Standardization of Aviation Ground Support Equipment, Final Report, 28 June 1983.

response to the recommendations of an earlier Industry/DoD study of automatic testing issues, completed in 1980.

Each of the above initiatives addressed acquisition or inventory management of test equipment. Coordinated action with respect to test equipment support dates back to 1967, when the JLC established the Joint Technical Coordinating Group for Metrology and Calibration. That group was tasked to promote increased standardization in the calibration practices of the Military Departments. It achieved some successes in the consolidation of duplicative calibration facilities -- an effort that began in 1975 with the establishment of a separate subgroup for consolidation of calibration services. This subgroup conducted studies of the feasibility and cost-effectiveness of consolidation on a regional basis. Some consolidation has occurred as a result, but the subgroup's recommendations for restructuring the calibration services in Europe were never approved. Similarly, recommendations, emanating from outside the calibration community, to centralize management and institute a Joint-Service Metrology and Calibration Center have not been acted upon.

MILITARY SERVICE INITIATIVES

Army

For the past 5 years, the Army has been in the midst of an extensive program to improve its management and support of TMDE. In 1979, it introduced a new TMDE calibration and repair concept. The old concept was characterized by (1) split responsibility for calibration and repair and (2) two levels of field calibration. The new concept, selected as a result of a comprehensive study,[5] provides total TMDE calibration and repair from a single source on an area-basis. It also assigns to the Army Materiel Command (AMC) (previously

[5] Department of the Army, "Concept Study for Improved Army-Wide TMDE Calibration and Repair Operations," March 1977.

DARCOM) responsibility for the management and control of all calibration and repair of common TMDE, as well as for selected special-purpose TMDE.

Also in 1979, AMC announced that it would adopt the AN/USM-410 EQUATE as the Army's standard general-purpose ATE for use at general support and depot levels. The policy for determining whether system-peculiar ATE planned for, or already in development for, new weapon systems would be acceptable in deviation from the AN/USM-410 EQUATE was promulgated in 1980.[6] That policy, in effect, emphasizes the benefits of standardization and permits a one-time cost increase to convert planned ATE to the AN/USM-410 EQUATE when long-term cost or readiness benefits warrant.

The decision to use the AN/USM-410 EQUATE as the standard ATE in the Army was followed closely by the establishment of the TMDE Modernization Program. That program, which was developed jointly by the U.S. Army Communications-Electronics Command (CECOM) and the U.S. Army Signal Center, was designed to correct many of the Army's longstanding problems with TMDE. Under the program, the Army would replace obsolete manual ETE with commercial off-the-shelf equipment. In the program's first year (FY81), 5 items (types of test equipment) were procured (total count of 3,600), replacing 21 different makes and models in the inventory. In FY82, 10 items were procured, replacing 650 makes and models. With the subsequent TMDE management reorganization in 1982 (see below), responsibility for the program was transferred to the Product Manager, TMDE Modernization, and the program expanded to non-CECOM items.

In April 1982, the Secretary of the Army designated the Commanding General, AMC, as the Army's TMDE Executive Agent responsible for TMDE acquisition, logistics, and financial management, and AMC's Deputy Commanding

[6] Department of the Army, "Implementation Plan for Single ATE (General Support and Depot) Policy," AMC, June 1980.

General for Materiel Readiness as the Executive Director for TMDE. These and other actions resulted in the Army establishing a centralized TMDE management structure consisting of three key activities:

- Centralized TMDE Activity, Lexington, Kentucky; responsible for equipment acquisition approval and TMDE evaluation, among others;

- U.S. Army TMDE Support Group, Huntsville, Alabama; responsible for TMDE calibration and repair, operation of primary standards laboratories, and assessment of TMDE supportability;

- Program Manager for TMDE, Fort Monmouth, New Jersey; responsible for the TMDE modernization program, development of ATE languages, and TMDE funding.

This centralization of the Army's traditionally dispersed TMDE management structure, which had been recommended by an earlier study,[7] was recommended by a recent study conducted by the Department of the Army TMDE Action Team (DATAT), which was undertaken at the request of the Assistant Secretary of the Army (Installations, Logistics, and Financial Management).[8] The DATAT report, besides recommending a centralized management structure, identified numerous other actions for improving the Army's management and support of test equipment. Those recommendations were approved and a plan to monitor Army-wide implementation was established. Several of the specific initiatives undertaken as a result of the DATAT report are identified below:

- Policy. In April 1984, the Army updated its TMDE policies by issuing Army Regulation 750-43, "Test, Measurement and Diagnostic Equipment." This regulation provides improved procedures for requirements identification, selection, acquisition, and life-cycle support for all types of TMDE.

- Systems Approach. Traditionally, the Army has acquired and fielded TMDE on an incremental basis. Now, the Army is determining the mission requirements of its maintenance organizations and the best mix of TMDE to meet those requirements. The Program

[7] LTG J. M. Heiser, Jr., USA (Ret.), "Assessments of DA/DARCOM Test, Measurement, and Diagnostic Equipment Program," September 1979.

[8] Department of the Army Test, Measurement and Diagnostic Equipment Action Team (DATAT) Final Report, March 1982.

Manager, TMDE, is pursuing this approach, starting in FY85 with the High Technology Motorized Division stationed at Fort Lewis, Washington. A reduction in overall numbers of TMDE is anticipated from this approach.

- Test Equipment Modernization Program. This program was originally focused on FSC 6625 test equipment for which CECOM is the inventory control point. In September 1983, it was extended to other FSCs but the funding was not increased.

- TMDE Support. The Army recently completed a comprehensive study of TMDE support, including automatic calibration, which was mandated by Congress.[9]

Another Army initiative, with a much broader impact than just TMDE, was to change its maintenance doctrine. In 1982, the Army eliminated general support maintenance units from the corps area and replaced them with intermediate (rear) units located behind the corps rear boundary. This change has had a far-reaching impact on the Army's ATE requirements. With the intermediate (rear) units requiring little mobility, the deployment, operational use, and support of the field-level version of the AN/USM-410 EQUATE has become more feasible. At the same time, the doctrine mandates highly mobile ATE for assembly testing and repair by intermediate (forward) maintenance units (formerly direct support) in corps, division, and forward areas.

Marine Corps

The primary test equipment initiative of the Marine Corps is to develop its own ATE standardization program. That program, which is scheduled to enter full-scale development in 1985, emphasizes modular architecture and commercial off-the-shelf test instruments, using a standard, commercial data bus. The Marine Corps is planning to field the new ATE at all maintenance echelons requiring ATE for fault isolation of assemblies and modules after they are removed from the end item. It will be configured as bench-top or rack-mounted equipment and installed in maintenance vans.

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[9] Deputy Executive Director for TMDE, "Final Comprehensive Report on the U.S. Army Calibration Program," Department of the Army, July 1984.

Navy

Navy initiatives to control or reduce the proliferation of general-purpose ETE date to 1969, when the Naval Material Command (NAVMAT) delegated centralized management responsibility for general-purpose ETE to the Naval Electronic Systems Command (NAVELEX). In exercising its authority, however, NAVELEX was hampered by the lack of agreement on what constitutes general-purpose ETE. As a result, much of the Navy continued to procure ETE under the guise of special-purpose ETE beyond NAVELEX control. NAVMAT attempted to solve this problem in 1973 by establishing an ETE Board, responsible for determining whether ETE is either general or special purpose.[10] The ETE Board eventually developed a standard item list (MIL-STD-1364 (Navy), "Standard General Purpose Electronic Test Equipment"), with NAVELEX responsible for keeping the list up to date and restricting, whenever possible, new general-purpose ETE procurements to items on that list. It also developed a special approval process for use when requirements dictate deviating from the standard item list -- MIL-STD-1387 (Navy), "Procedures for the Acquisition of Non-Standard General Purpose Electronic Test Equipment."

A recent initiative by NAVELEX was the establishment of a "General Purpose ETE Assets Screening Pool" program, which consists of a central registry of Fleet assets in excess of allowance for redistribution. This program was established in response to a General Accounting Office report which noted that, with the exception of a limited Naval Sea Systems Command (NAVSEA) program, the Navy had no such capability.[11] More recently, NAVELEX

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[10] NAVMAT Instruction 5430.52, "Electronic Test Equipment; classification and assignment," 10 May 1973, implemented by NAVELEX Instruction 5420.12, "Naval Material Command Electronic Test Equipment Classification Board; policies and procedures," 26 October 1973 (Revision A, dated 21 April 1976).

[11] General Accounting Office, "Survey of DoD's Management of Automatic and General-Purpose Electronic Test Equipment (LCD-80-106)," Letter Report to the Secretary of Defense, B-199353, September 4, 1980.

has begun installing an automated general-purpose ETE data base. The first version of that data base, excerpted from the more comprehensive Metrology Automated System for Uniform Recall and Reporting (MEASURE) data base, was installed in mid-1984, but it is incomplete (NAVELEX estimates that 30 percent of the Navy's inventory, based on cost, is not included in the data base). NAVELEX is now enhancing this data base.

Navy initiatives with regard to automatic testing date to the mid-1970's when the Assistant Secretary of the Navy for Research and Development requested that a study be conducted to define the problems and develop solutions of the Navy's use of ATE. This study was conducted by representatives of NAVMAT, Systems Commands, field activities, Fleet, and industry. The resulting report, known as the "Marcy Report,"[12] identified numerous problems and developed a variety of recommendations to solve them, including:

- Establishment of a central ATE management group within NAVMAT, reporting directly to the Chief of Naval Material.
- Education of management personnel in the technical and management issues involved in weapon system acquisition, including the practical problems of BIT and off-line ATE hardware/software.
- Provision of quick relief to the Fleet by: (1) initiating engineering changes (reliability improvements) for high-failure items of prime equipment as well as ATE, (2) establishing "tiger-teams" to respond to Fleet ATE problems, (3) developing organic test programming capabilities, and (4) prohibiting deployment of off-line ATE without prior approval for Service use.
- Development of a new family of general-purpose ATE and institute policy requiring the Chief of Naval Material approval of any off-line ATE acquisition.
- Initiation of research and development programs in automatic testing technology.

In addition to this in-house effort, the Navy also requested an independent assessment of its ATE efforts from industry. The Industry Ad Hoc ATE Project

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[12]Assistant Secretary of the Navy (Research and Development), Report on Navy Issues Concerning Automatic Test, Monitoring and Diagnostic Systems and Equipment, February 1976.

as chartered in November 1975, and its final report was published in April 1977.[13] This effort, in turn, was extended into the Industry/Joint Services Automatic Test Project when the Navy recognized that its problems in exploiting automatic testing existed DoD-wide. As noted earlier in this chapter, the latter study was completed in June 1980, with many of the recommendations pursued by joint working groups under auspices of the JLC Automatic Testing Panel and the NSIA Automatic Testing Committee.

The Navy began implementing most of the actions recommended in the "Marcy Report" in 1976. A Test and Monitoring Systems Project Office was established, with responsibility for reviewing acquisition projects; conducting coordinated research and development efforts in testing technology; developing ATE policies, procedures, and management tools; and establishing a list of "approved ATE." In a 1980 NAVMAT reorganization, that project office was transferred to NAVELEX.

NAVAIR, in assessing the lessons learned from VAST, formulated its ATE plans for the 1980's and beyond and documented them in the NAVAIR ATE Program Plan (dated January 1978, approved and promulgated in 1979). The goals of that plan included:

- Integrate ATE program management;
- Improve ATE acquisition;
- Design avionics for testability and maintainability;
- Minimize the variety of ATE;
- Consolidate and improve ATE software;
- Improve the quality of TPSs;
- Attain full and timely organic support capability.

[13] Industry Ad Hoc ATE Project, Report of Industry Ad Hoc Automatic Test Equipment Project for the Navy, 3 vols., April 1977.

key goal was to minimize the variety of ATE, with the ultimate objective ng an ATE inventory with standardized, modular hardware and software ments using a single, standard test language. To achieve that goal, the n defined a functional family of common ATE to be used in the 1980's, and cribed a new ATE project, the Consolidated Support System (CSS), for use in : 1990's and beyond.

The system definition phase of the CSS program started with contract ırds to five competing contractor-teams in January 1982 and was completed in ;ust 1983. The Navy has completed its evaluation of the contractor's forts and anticipates releasing a request for proposal in January 1985, with ıtract award for full-scale development expected in mid-1985. NAVAIR's rategy emphasizes supportability, modularity, technology transparency (i.e., signed for technology updating), rapid reconfigurability, operational evaluion of prototype, and ability to compete the production phase, with liveries starting in 1992. The total CSS Program is estimated to cost .7 billion.

NAVSEA's initiatives in automatic testing are centered in the pport and Test Equipment Engineering Program (STEEP). Initiated in tober 1978, STEEP's goal is to improve Fleet support of electronic modules d printed circuit boards (PCBs) by using digital card testers at ganization- and/or intermediate-maintenance activities to identify PCBs that n be repaired in the field. A subsequent field test of this concept, concted from 1979 to 1981, resulted in (1) the AN/USM-465 being selected as the andard intermediate-level ATE for testing digital PCBs and (2) repairs of lected PCBs being authorized at the intermediate level. Additional field sts, completed in 1983, resulted in NAVSEA extending authorization of gital card testers and some PCB repairs to the organizational level.

Between July 1981 and July 1984, the Navy established 75 STEEP sites (51 shipboard, 24 ashore), procured 100 AN/USM-465s digital card testers, and developed and installed about 430 unique TPSs (total density 10,500). In FY85, the number of STEEP sites is scheduled to increase to 110, the AN/USM-465 inventory to several hundred, and the number of unique TPSs to 1,200 (total density of 20,000); the annual growth of unique TPSs is projected to be 300 to 500 over the next 5 to 7 years. To assist in the management and support of these TPSs, the Navy established an ATE/TPS Coordination Center to: (1) provide a point of contact for all TPS users, (2) maintain ATE/TPS configuration and deployment status accounting, (3) process TPS trouble reports, and (4) provide management information. The center is located at the Fleet Analysis Center, Corona, California, with computer facilities for deployment and configuration information and for TPS maintenance/development tools.

Among the many activities of the ATE/TPS Coordination Center, it distributes quarterly to each ship the Catalog of Automatic Testing Capability for Electronic Modules/Printed Circuit Boards, identifying the prime equipment and the specific modules for which TPSs are currently available and the specific test sites involved. It also publishes the Master Test Program Set Index, listing the available TPSs by ATE-type and weapon system. Furthermore, it supports use of the Hierarchical Integrated Test Simulator, a new digital automatic test program generator that was developed by the Naval Air Engineering Center with contractor support. That simulator is planned as the standard Navy digital automatic test program generator for the future; it provides more capability than previous generators used by the Navy, especially with regard to large-scale and very-large-scale integrated circuits.

Air Force

In 1976, the Air Force, in response to its longstanding problems with ATE (proliferation of test systems, inadequate fault detection and isolation, escalating acquisition costs, short life cycles, low system availability, and a lack of corporate memory of lessons learned), established the MATE Program as a systematic approach to the acquisition of ATE to support future weapon systems. The concept of the MATE Program was based upon using standard ATE architecture, interfaces, and software such that different ATE stations could be configured from a common set of ATE modules, and reconfigured to accommodate weapon system modifications. The concept/validation phase for the MATE Program was conducted from June 1978 to June 1981, with two competing contractors developing a uniform ATE architecture with standard interfaces and "intelligent" stimulus/measurement instruments and the management/technical tools. This phase resulted in a set of MATE Guides that provide the standards, specifications, and procedures for implementing each contractor's concept:

- Electronic Test Equipment Acquisition Guide;
- MATE Development Guide;
- Avionics Testability Design Guide;
- Production and Operational Support Guide;
- Test Program Set Acquisition Guide.

In July 1981, the full-scale engineering development contract ($55 million) was awarded to refine the MATE Guides, develop the MATE data base system, and demonstrate MATE in two ways: (1) by applying MATE concepts to the development of the intermediate automatic test system for the A-10 inertial navigation system, with the contractor responsible for ATE integration, and (2) by providing technical support to the Air Force for the development of the Depot Automatic Test System for Avionics, with the Air Force responsible for ATE integration.

The MATE Program, apart from its importance to the Air Force, has had a significant influence on the other Military Departments as well. It has encouraged a systematic management approach to the acquisition and support of ATE as a support system, not a stand-alone item. Furthermore, major portions of the MATE Guides are under review for adoption as Joint-Service Guides under the JLC Automatic Testing Panel. Over 50 percent of the JLC's automatic testing program budget for the years 1978 through 1983 (the budget totaled $250 million for those years) was MATE-related.

The Air Force's commitment to MATE was demonstrated by its publication of the implementing regulation in early 1984.[14] The regulation applies to all Air Force Systems Command (AFSC) and Air Force Logistics Command (AFLC) organizations that acquire, modify, replace, and support weapon systems. The regulation includes the policy, organizational structure, waiver process, and authority required to make MATE the standard Air Force ATE. It implements the use of the detailed guides, control and support software, and automated tools produced by the MATE Program. It also establishes a MATE Operations Center to perform MATE qualification testing for hardware and software modules and to provide access to the MATE automated management tools and training system. The MATE Operations Center, established at the San Antonio Air Logistics Center, Texas, is also responsible for configuration control, maintenance, and distribution of MATE guides, specifications, standards, and other documentation.

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[14] Air Force Systems Command (AFSC) and Air Force Logistics Command (AFLC), "Policy for Modular Automatic Test Equipment (MATE)," AFSC/AFLC Regulation 800-23, 25 January 1984.

In 1979, AFLC identified a need for information on what ATE was deployed and where and how it was being utilized. The system capability and data automation requirements for such a system were submitted and approved in 1980. Development of that system, Test Equipment Reporting and Management System (TERMS), was completed in 1981, and pilot-implementation began in mid-1982 at five air bases. The system consists of a centralized data base that is updated on-line by the air bases, which report all transactions involving installed ATE. The formatted input data include ATE utilization records, ATE status records, and station inventory records. Worldwide implementation of TERMS is awaiting Air Staff authorization.

The San Antonio Air Logistics Center is in the process of modifying TERMS to interface with other systems (such as the C104 ATE data bank that contains information on ATE inventory and operating parameters, the D039 Item Manager's inventory asset balance for equipment items, and the MATE data bank). When completed, the modified TERMS will provide Major Air Force Commands access to the system (currently, only the individual bases have access to it) and use of several software models.

In 1980, the Aerospace Guidance and Metrology Center (AGMC) found that the Air Force's Precision Measurement Equipment Laboratories (PMELs) had problems calibrating and repairing test equipment and that their backlogs and reliance on contractor support were increasing. In 1981, AGMC convened a worldwide PMEL conference to identify the causes of those problems and the actions required to correct them. Some of the corrective actions that occurred as a result of that conference included:

- Policies/Plans. Additions were made to the War and Mobilization Plan which required planning for intermediate-maintenance support of test equipment (previously, the assumption had been that the nearest PMEL could provide support, not recognizing that all PMELs are different).

- Equipment. To reduce the obsolescence of PMEL equipment, a significant increase in funding for the replacement of that equipment was programmed in the POM.

- Procedures. Procedures were developed to improve item management of PMEL standards and to reduce the amount of test equipment fielded without calibration requirements documentation; AGMC-prepared calibration procedures were reorganized and the procedure verification process was tightened.

- Personnel/Training. Proposals (still under consideration) were developed to improve retention and increase the experience level of PMEL personnel.

Another AGMC initiative was to develop a better approach for calibrating ATE. Traditionally, the Air Force calibrated ATE by removing the tester-replaceable units from the ATE at specified intervals and then sending those units to a PMEL for manual calibration. This approach had many disadvantages, including:

- ATE downtime was significant; the ATE was down any time a tester-replaceable unit was removed, thus, the ATE was seldom completely assembled.

- Programmable features could not be exercised in calibration; timing and time-related problems with the ATE were either masked or ignored, so that those units that function on the test bench might not work in the ATE.

- System performance was not checked; no compensation or allowance for cabling, loads, switching, or other sources of signal degradation between the tester-replaceable units and the UUT was possible.

- The tester-replaceable units were subject to damage in transit between the ATE site and the PMEL.

- High levels of integration in the ATE made off-site calibration difficult or impossible; many measurement/stimulus functions previously performed by individual tester-replaceable units were often implemented at the card level. Removal and calibration of those functions in the PMEL was difficult.

- The tester-replaceable units were not calibrated in their operational, physical, and electrical environment.

To overcome the shortcomings of off-site calibration, AGMC developed an on-site calibration concept, the Portable Automatic Test Equipment Calibrator, with the following features:

- Portable calibration standards are brought in protective cases to the ATE site.
- The ATE is calibrated as a total system, addressing only the required functions to required accuracies.
- Calibration is performed as close to the UUT interface as possible.
- PMEL personnel perform the ATE calibration with user (ATE operators) assistance and participation.
- Most standards are programmable, providing as totally automated a calibration procedure as possible.

Between 1976 and 1984, the Air Force procured 210 portable calibrators, with most assigned to PMELs.

In response to problems associated with transferring program management responsibility from AFSC to AFLC for major weapon systems during the 1970's, the Air Force established in 1982 a Deputy Chief of Staff for Acquisition Logistics at AFSC Headquarters. The responsibilities of that office include management of acquisition logistics, product assurance, standardization, computer resources, and support equipment and automatic testing policy. AFLC then established a single system manager for automatic test systems at San Antonio Air Logistics Center and designated it the AFLC focal point for readiness and logistics support of ATE. Responsibilities of the automatic test system manager include planning for logistics support (in coordination with the weapon system program office and its deputy program manager for logistics), screening of the inventory for equipment capable of satisfying new testing requirements, evaluating SERDs, and managing all fielded ATE.

Deputy program managers for logistics have been assigned to AFSC system program offices since the early 1970's. To enhance the role of acquisition logistics and its potential for influencing weapon system design, the Air Force recently redesignated the Air Force Acquisition Logistics Division (an AFLC field organization within AFSC, including the deputy program managers for logistics) as a joint AFSC/AFLC organization, known as the Air Force Acquisition Logistics Center. Further changes in management structure, policies, and procedures can be anticipated as a result of continued dissatisfaction with the way support equipment is managed, evidenced by a recently completed Air Force study.

In March 1984, the Support Equipment Acquisition Review Group was established at the request of the Assistant Secretary of the Air Force (Research, Development, and Logistics) and formally chartered by the AFSC and AFLC Commanders to study the entire support equipment acquisition process. In its final report, which was issued in July 1984, the Review Group identified 19 major problems in support equipment acquisition and made 107 recommendations to solve them. In assessing the operational impacts of the support equipment problems, it concluded that shortages in support equipment (estimated at a cumulative value of $1.5 billion) do not impact peacetime mission accomplishment because

> . . . extensive workarounds and personal ingenuity are being used to accomplish the mission, but that these shortages could potentially have mission impacts if we are stressed, and particularly if we are stressed in more than one direction at the same time.[15]

The recommendations of the Review Group have been approved by the Air Force Secretariat, and the Air Staff has instituted a tracking system to monitor their implementation.

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[15] Support Equipment Acquisition Review Group Final Report, July 1984. The report defines support equipment as comprising two categories: TMDE (comprising precision measurement equipment, ATE hardware, ATE software, TPSs, and special test equipment) and ground support equipment.

SUMMARY

The preceding synopsis of DoD initiatives to alleviate the shortcoming in test equipment management and support is neither complete nor exhaustive. Nevertheless, it demonstrates that the Military Departments are well aware of the shortcomings and have already launched programs to correct many of them. The synopsis also documents the near absence of OSD participation in the initiatives, which we believe has resulted in some of the initiatives being less successful than anticipated. In the following chapter, we set forth several specific actions OSD should take to solve some of DoD's fundamental management problems with test equipment.

4. RECOMMENDED ACTIONS

SYNOPSIS

The DoD has a long history of problems in acquiring and supporting test equipment. The OSD, the Military Departments, and industry associations have sponsored numerous studies, task forces, inspections, and panels to document the problems, identify causes, and recommend solutions. Some of those efforts focused on particular technical issues, others addressed broader, DoD-wide issues. Regardless of their focus or sponsorship, however, they have routinely documented the same problems.

The DoD has too many different types of ETE, and the procedures for controlling further inventory growth are not effective. Much of that equipment is obsolete, and so it is difficult to support. It is also excessively costly because of requirements that much of it be built to military specifications, rather than to use commercial design standards.

The DoD has not effectively controlled the growth of ATE. Furthermore, much of that equipment suffers from rapid obsolescence, insufficient throughput capacity, and inadequate performance.

The DoD has difficulty acquiring TPSs in a timely manner. Many are not as effective as planned, and most require excessive run times to fault-isolate problems. All need to be updated within a few years of initial fielding.

In response to those problems, the OSD and the Military Departments have undertaken numerous corrective efforts. Those that have focused on the acquisition process show some long-term potential. Greater emphasis is being placed on support during weapon system development, procurement of test equipment is being delayed until weapon system designs stablize, and standardized ATE is being developed.

Many of the corrective efforts, however, have resulted in the establishment of another Joint Service study group or panel, usually to examine a specific technical issue. Those examinations have had a tendency to be very lengthy and seldom have resulted in decisive actions.

The few efforts that have addressed the management and support of test equipment after it enters the inventory have been launched with considerable enthusiasm. All too often, however, they have lacked the support, either within a Military Department or throughout the DoD, that is required to carry out their original objectives.

CONCLUSIONS AND RECOMMENDATIONS

The DoD continues to be plagued with test equipment problems because (1) the associated technical issues have been and continue to be difficult to overcome, (2) the responsibility for test equipment management within the Military Departments is fragmented, and (3) the OSD has not provided the leadership in effecting improvements in the management and support of fielded test equipment.

For the past several years, USDR&E, working both with the Military Departments and the JLC, has been spearheading DoD's efforts to overcome the technical problems. Those efforts, many of which are now on the verge of yielding significant benefits, have focused primarily on changes to the acquisition process. They also have included the funding of research and development programs to resolve specific technical problems.

Since the early 1980's, each of the Military Departments has established some type of single manager for test equipment. For the most part, however, those single managers have been assigned responsibility for just one small segment of test equipment, usually general-purpose ETE. The responsibility for special-purpose ETE, for example, continues to be fragmented among numerous program and system managers. As a consequence, the Military Departments have made some progress toward improved test equipment management, but additional improvements, many of which are substantial, are still required.

The primary effect of OSD's lack of involvement in the management and support of test equipment has been to reinforce the Military Departments' perception that test equipment is not a high priority item. Yet, the DoD's investment of approximately $30 billion in test equipment and the effect of that equipment on weapon system readiness and sustainability makes that position no longer tenable. To the contrary, those factors suggest substantial and immediate involvement.

We believe that the efforts of the USDR&E and the Military Departments to overcome the technical problems with test equipment need to be augmented with complementary actions focusing on the management and support of fielded test equipment.

Furthermore, we believe that the Assistant Secretary of Defense (Manpower, Installations, and Logistics), ASD(MI&L), must be the catalyst to effect those actions within the DoD. We recommend that he charge the Director, Maintenance Policy, to take the following actions fundamental to an effective test equipment management program within the DoD:

- Develop a DoD-wide preferred items list for ETE, as well as procedures to assure that program and item managers use the items on that list to satisfy ETE requirements;

- Institute reporting of ATE performance and availability;

- Establish the collection of TPS run times and performance;

- Draft a DoD instruction that prescribes policy and procedures for managing and supporting test equipment.

These actions constitute a small, first step toward improving management and support of test equipment within the DoD. The first action, development and use of a preferred items list, is the most effective approach to reducing ıe proliferation of ETE within the DoD. The ramifications of such a list can : far-reaching, from reducing ETE procurement costs to improving ETE support. ıe second and third actions are designed to enable the Military Departments ɔ identify shortfalls in the performance of fielded ATE and TPSs. Currently, he Military Departments do not have formal procedures for collecting such nformation. The fourth action fills a void in DoD policy that is partially esponsible for many of the current inadequacies in test equipment management nd support.

The Director, Maintenance Policy, certainly cannot take the actions we ecommend in isolation. He will need to work closely with representatives of .he USDR&E and the Military Departments to effect even the most straightfor- ard action. Nevertheless, he will offer a fresh perspective on what needs to e accomplished and how to do so most effectively. He will also be in posi- :ion to ensure that the Military Departments follow through with their commit- ents and programs to improve the management and support of fielded test :quipment.

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